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RESEARCH PROGRAM ON INTELLECTUAL DEVELOPMENT.

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UNDER THE DIRECTION OF PROFESSOR BRUNER, THE CENTER FOR COGNITIVE STUDIES AT HARVARD UNIVERSITY HAS CARRIED OUT A SERIES OF STUDIES ON THE DEVELOPMENT OF COGNITION. THERE HAVE BEEN OVER 30 EXPERIMENTS ON THE GROWTH OF PERCEPTION, PROBLEM-SOLVING, AND REASONING BETWEEN THE AGES OF 3 AND 10, IN PURSUIT OF A THEORY TO ACCOUNT FOR THE CHANGES IN INTELLECTUAL FORMATION THAT OCCUR IN THE GROWTH OF THE CHILD. EXPERIMENTS HAVE BEEN CARRIED OUT NOT ONLY WITH AMERICAN CHILDREN, BUT ALSO WITH BUSH CHILDREN IN SENEGAL AND THEIR URBAN COUSINS IN DAKAR, WITH MESTIZO CHILDREN IN RURAL MEXICO AND THEIR COUNTERPARTS IN MEXICO CITY, AND WITH VARYINGLY ACCOUNTABLE ESKIMO CHILDREN IN ALASKA. THE RESEARCH ON THE DEVELOPMENT OF PERCEPTION, THOUGHT, AND LANGUAGE HAS BEEN OF TWO PRINCIPAL KINDS. ONE KIND DEALS WITH THE MANNER IN WHICH CHILDREN LEARN TO MAKE INFERENCE, TO CARRY OUT SORTING TASKS, AND TO IMPOSE ORDER ON THE ENVIRONMENT. THE SECOND TYPE RELATES TO THE MANNER IN WHICH CHILDREN LEARN TO SEARCH THE VISUAL FIELD. COMPUTER ANALYSIS OF EYE MOVEMENTS IS USED IN THE LATTER TYPE OF STUDY. IN THIS REPORT 11 OF THESE STUDIES ARE DESCRIBED AND CONCLUSIONS ARE DISCUSSED. (JC)

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# RESEARCH PROGRAM ON INTELLECTUAL DEVELOPMENT

Cooperative Research Project # E-020

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## STATEMENT OF PROBLEM

The Center for Cognitive Studies at Harvard University under contract # E-020 with the Office of Education from February 1, 1964, through June 30, 1965, has carried out a series of studies on the development of cognition. There have been some thirty or more experiments on the growth of perception, problem solving, and reasoning between the ages of three and ten, in pursuit of a theory to account for the changes in intellectual formation that occur in the growth of the child. Experiments have been carried out not only with American children, but also with Bush children in Senegal and their urban cousins in Dakar, with Mestizo children in rural Mexico and their sophisticated counterparts in Mexico City, and with varyingly accountable Eskimo children in Alaska, opening up new fields of inquiry in the cross cultural study of intellectual development.

The research undertaken on the development of perception, thought, and language has been of two principal kinds. One is concerned with the progress of the child between the ages of three and ten from representation of the world in terms of habitual response patterns to a representation in terms of images to a final representation in which to these prior forms is added the powerful device of representation in symbolic terms of language. These studies are best illustrated by experiments dealing with the manner in which children learn to make inference, learn to carry out sorting tasks, and learn to impose order on their environment.

The second type of study relates to the manner in which children learn to search the visual field. These studies, using computer analysis of the eye movement patterns, have shown how children modulate their eye movements to take account of the visual environment. Children do not look so frequently at informative regions and do not always adequately cover the whole scene as adults do. They take twice as many very small visual steps and often linger too long on details. This evidence is clearly related to the child's piecemeal perception and his use of highly specific visual cues for recognition of objects. We are now considering to what extent learning to read is affected by the eye patterns and whether there are exercises that can be introduced prior to reading that might make eye movements more suitable to the task of reading. It is interesting to note that well before the children in our culture get to the point of being able to read, they are well adjusted to materials presented in horizontal arrays.

### Theoretical Background and Hypotheses

It is the hope, then, of all who have collaborated under this "Research Program in Intellectual Development" that the study of the nature of efficiency and inefficiency in strategies used by human beings in thinking and problem solving will contribute greatly to our quest for understanding how human beings increase their mastery in achieving and using knowledge. The central theme is that mental growth can be conceived as the development of representational systems in the growing human being. Such systems are strongly influenced by culture and by man's evolutionary

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history. Yet, though culture and evolution are crucial to an understanding of cognitive growth, it is still a psychological explanation that is required.

Development involves three modes of representation -- enactive, ikonic, and symbolic. Representation can be viewed in terms of the medium or mode of knowing used; that is, by action, by image-forming, and by use of a symbolic system such as language. The medium being used is inferred from observable behavior. But it can also be viewed in terms of the objective of representation, why things are represented in a particular mode. Language, for example, may be a symbolic means of describing states and images, or it may serve to guide action or describe a sequence, or to describe abstract relations among states. A symbolic relationship translated into imagery may better serve as a guide or support for action. The enactive mode supports an "habitual" pattern which in turn becomes a program in the sense that various "substitutes" can be inserted without disrupting the overall act. In addition, enactive representation may lend support to symbolic activity as well as lending support to looking. Finally, the major function of enactive representation may be the guidance of action itself.

Enactive Representation

Piaget's observation of six- and seven-month-old infants reaching for objects reveals "the true nature of the object peculiar to this stage-- a mere extension of the action" (1954, p. 22). The separation between percept and response is unclear; sight of an object leads to action, which in turn evokes an image after the object is removed. By the latter half of the first year a strong bond has been established between perception and action. Three basic theories attempt to explain how this develops.

According to the nativistic view, from birth organisms are capable of discriminating features of the environment. This view is supported by experimental work of an anatomical nature by Hubel & Wiesel (Hubel, 1963), by studies of visual discrimination in newborns by Kessen (1965) and Bower (1965) and by the constructionist (visual preference) work of Fantz (1965) and Piaget (1954). These works, considered in view of von Senden's observations on the restored sight of the congenitally blind (1960) suggest that while objects are "constructed", the construction takes place within a prepared and innate visual framework. Held's work (1965) supports our proposal that the origin of enactive representation is found precisely in the reafference that serves to relate the requirements of action to the properties of the visual field.

With these basic considerations we move on to the sensori-motor phase of development expounded by Piaget (1954). In this phase action and external experience fuse. Eventually, so observation shows, the child, in an egocentric manner, can hold an object in mind with little necessity for grasping or touch. The next stage of development involves the coordination of action schemata into a more generalized schema, in which

action is now "fused" with other events into something that is more genuinely a representation of the world.

In our attempt to understand how, finally, the separation of action and percept occurs we turn to Mandler's experiment (1962) on serial response to an image of a maze. After achieving mastery on a complex maze of switches without sight of the maze, Mandler's subjects continued "running through" until several reported a change in how they were proceding. A "print out" occurred -- their image consisted of a true path, rather than a connected series of overt movements. Lashley argues in his famous Hixon Symposium paper (1951) that orderly serial motor activity depends on a matrix of background representational processes in the form of a simultaneous or "atemporal" representation. An abstracted schema can become the basis for action-free imagery. Drake's elaborated replication (1964) of earlier experiments by Emerson (1931) and Werner (1948) supports this view. For example, the child's task is to reproduce on his own peg board the position of a ring on the experimenter's board. Bodily reorientation and intervening motor activity greatly affects the younger (three-year-old) children. Finally, the work of Leeper (1963), and "sensori-tonic" theorists such as Werner and Wapner (1956) suggest that many factors affect the gradual separation of percept and action; but the possibility remains that this separation is never complete.

Ikonic Representation

By the time a child approaches his first birthday he is able to represent his experiences by image or spatial schema fairly separated from action. However, his imagery is aided by manipulation. By investigating the nature of perception in this age group we gain an understanding of the way in which the child organizes his cognitive activity. Gibson and Olum (1960) described perception at this age as (1) "stuck", (2) "autistic", (3) diffuse in organization, (4) "dynamic", (5) concrete, (6) egocentric, (7) wavering in attention, (8) organized around minimal pointable cues. The work of Witkin and his colleagues (1962) on difficulties children have in dealing with "camouflaged" or "embedded" figures supports the "stuckness" characteristic of the young child's perception (difficulty the child has in trying to shift in set) as well as the concrete and manipulative features. The difficulty young children have in attempting to reconstruct a whole picture from its parts or recognizing dotted outline figures is supported by experimental findings of Mooney (1957), Piaget and von Albertini (1954).

We may infer from these and other findings a number of conclusions concerning the way perception in young children differs from adult perception. There appears to be little economy in early perception (Attneave, 1954). There seems to be a considerable amount of "one-trackness" or need for serial integrity in the way figures are viewed. There is less complexity of organization in the child's perceptual field; and the perceptual processes are motorically influenced. Piaget and Inhelder's work (1956) shows that due to the egocentric feature the child has difficulty

in "taking a view" external to himself. Experiments by Bruner and Goodman (1947) and Tajfel (1957) suggest that an extension of the egocentric influence is responsible for distortion in the perceptual field when the child represents his affective states. In addition, experimental work on perception in the young child has been most hampered by the characteristics of instability and high distractability. Titchner's (1908) early work on primary and secondary attention suggests that the child passes through a progression in developing stability.

The young child deals with surface cues which catch his attention. The research findings of our colleagues indicate that as he develops, a major challenge arises as he attempts to deal with deeper structures based on invariant features. Clementina Kuhlman directed her doctoral research to the hypothesis that the major vehicle of "thinking" in children is imagery and its manipulation. "Either the habit of using imagery is suppressed as language is learned; or it is retained during language acquisition and is adapted to the requirements of complex problem solving" (Kuhlman, 1960, pp. 109-110). In her study of the differences in mental and performance abilities of high versus low imagery young children, Kuhlman found that high imagery children exhibit higher performance on a task in which they must learn to associate arbitrary verbal labels with pictures, but their inferior conceptual performance is a result of their use of surface features in grouping.

Observations of Reichard et al (1944), Werner (1948), N.E. Miller (1934) and others indicate that until age eight or nine the young child prefers a perceptual basis for sorting objects. As we survey the development of symbolic representation, we find that this, too, is based on imagery. Brown (1958) shows that the child's vocabulary usually grows from small picturable categories to wider and more subtle "picturable" ones. To summarize our discussion, the child is able to recognize a differentiation between himself and the external world as ikonic representation becomes established. Ostensive definition is the critical vehicle in the child's thinking. This is the setting for the development of symbolic representation.

## Symbolic Representation

Certain conditions are necessary for a person to be able to utilize his cognitive processes: He must be able to free himself from the immediacy of present stimuli, to conserve past experiences into a system or model, and to have developed an efficient system for storing and retrieving information. Study of the ontogenetic features of language, particularly the universal properties of early language, suggests that symbolic representation is a basic and innate activity which functions in man's use of his cognitive processes. Symbolic representation is responsible for translating experience

into language. Language is a major, specialized but innate system of representation, which is elaborated through acculturation. Primary among the features of symbolic representation is symbolic reference, the remote, arbitrary name given to an object, state, or activity. However, for the young child learning to talk, words function only as signs, not symbols (Brown and Berko, 1960 and Vygotsky, 1962).

The development of the"semantic function" of language is a slow, cumulative process (for an interesting description see Katz and Fodor, 1963). One of the universal characteristics of language is the difficulty the young child has in learning to recognize a semantically anomalous sentence such as "The wagon bites Johnny". In respect to Kuhlman's study of children with high imagery, we can readily see why learning symbolic reference is more difficult for them. Eventually the child questions not only objects whose "name" he does not know, but also queries the meaning of unfamiliar words used by other speakers.

Roger Brown's work (1956) has brought to light a second universal feature in the young child's language usage, that of categoriality and hierarchy. These can be attributed to basic properties of symbolic representation as well as language. Words are not limited in referring to a single instance or object, but rather include a class or group, which can be hierarchically arranged. These classifications are rule-bound, so that newly found instances may be added. Roman Jakobson refers to these features as combination and selection.

Language development usually follows an orderly sequence. Gestures precede vocalization. The child's "first language" consists of one-word holophrastic utterances. Around two years of age, the two word sentence develops (the P(x) form as described by Braine, 1963); these utterances consist of one restricted word or morpheme (the minimum unit carrying meaning) and one open morpheme. It is here that grammar enters. The child's utterances indicate he is aware of a set of rules that will allow basic combinations or words. This combinatorial nature of grammar allows endless generation of "sentences" to be formed, but none that are not of a syntactically legitimate nature.

As the child's knowledge of words and understanding of the rules of grammar develop, he produces sentences which contain three fundamental properties: subject-predicate, verb-object, and modification. The subject-predicate may be thought of as the x in "x is the function of y". The verb-object relationship is one of cause and effect; modification is the intersect of classes. Therefore, three basic symbolic processes can be referred to as function, causation, and intersect -- and these three may very well be innate processes. Eventually the property of transformation or rewriting affords him the opportunity for using passive, interrogative, or negative transformations to express equivalent utterances.

Consider the feature of effective productivity. Rules of grammar allow for the development of a highly productive system. Ruth Weir's perceptive study Language in the Crib (1962) gives examples of the extent to which young children practice these rules. Effective productivity is linked to the semantic function as well. Language has rules for the transformation of sentences that can transcend mere reference. If language is relevant to the real world, then the linguistic features of categoriality and hierarchy should also be features of the child's experiences. Upon examination we see this is not the case; language does not impose itself upon experience. Although words are not generally used counter to reality, the Whorfian hypothesis is not entirely valid. We must also reject Vygotsky's suggestion that language starts as dialogue, becomes a monologue, and as it is internalized into our thinking, becomes "inner speech". We propose that "language comes from the same basic root out of which symbolically organized experience grows".

Consider in more detail the internalization of the basic cognitive processes from language to thought. The maturing of the syntactical system is explained by Brown and Bellugi (1964) as developing through the contingent cycle that occurs between child and tutor in early childhood language learning. Furthermore, this appears to continue operating throughout the formative years. The three-stage reciprocal interaction consists of child utterance; tutor idealization and expansion; child copying and perfecting his original model. This however is not to be taken as mere imitation. Such a theoretical view is supported by McNeill's discussion (1966) of the early use of a holophrastic language, where one word stands for a sentence. A transition occurs which enables the child to use two or more word combinations, in effect, a sentence dictionary. This shift is "inconceivable without a syntactic component that gives words a productive benefit over holophrases". A second transition involves the buildup of a system of semantic markers; thus the word dictionary becomes the base for language development (with some syntactic differentiation).

A primitive grasp of the identity concept may be present at birth. With the development of gesturing, the earliest rudiment of communication, the infant has some concept that the "thing" he is pointing to he has experienced before. When the child has fully developed in the concept of an object, naming occurs.

Lashley's paper on serial order (1951) suggests that syntactical maturation can occur only as and after the child develops freedom from enactive representation. The syntactical sphere develops autonomously. Syntactic maturity is rapidly achieved. However, the child cannot yet organize experiences to correspond to syntactical rules. In order for language to become a tool of thought the child must achieve this syntactical organization of experience. Even though language may be well developed, enactive and ikonic modes of representation predominate unless the child receives special training in the symbolic representation of experience. In view of this we accept the linguists' concept that "language is an innate pattern, based on innate 'ideas' that are gradually differentiated into the rules of grammar" (McNeill, 1966, Chomsky, 1965, Katz, 1965).

## RELATED RESEARCH, PROCEDURES, AND FINDINGS

### CONCEPTUAL STRATEGIES - David Olson

The preschool child is highly receptive to the immediacy of a stimulus situation whereas the older child can withhold action and formulate a plan of hypothesis (Luria, 1961). The research reported here was based on the hypothesis that the strategy or sequence of decisions a child employs in a problem solving situation is a function of the child's stage of intellectual development and mode of representation. One would expect an enormous change in the strategies employed as the child develops and is able to make use of the powerful tools of symbolic representation.

Bruner, Goodnow, and Austin (1956) described the problem solving or concept attainment behavior of their adult subjects in terms of three major strategies: simultaneous scanning, successive scanning, and focusing. It was the intention of this study to examine the behavior of young children in a problem-solving situation for evidence of the origin of these strategies.

#### Procedure

The sample consisted of 95 children, ages 3, 5, 7, and 9, half from the Boston suburban area and half from Halifax, Nova Scotia. The apparatus consisted of a bulb board -- a horizontal panel of grey consisting of five rows and seven columns of dark red light bulbs, 1/2 inch in diameter, spaced 1/2 inch apart. Switches on the back of the apparatus permitted the experimenter to set each bulb on or off. When a child pressed a bulb set "on" it would light up; as the child lifted his finger to press the next bulb, the bulb would go off. A cover allowed the experimenter to reduce the matrix to 3 x 3, 5 x 5, or 1 x 4. The matrix of the bulb board was changed to match the size of the patterns presented.

The task required the child to determine which one of two or three patterns, paper models set over the bulb board, was the one "hidden" by the experimenter in the bulbs. The children were run under one of two conditions, "free" or "constrained". In the former condition the children were permitted unlimited choice of bulbs to solve the problem; in the latter, the children were limited to one press upon which to base their decision.

Three sets of patterns were studied in detail: (1) On a 3 x 3 matrix; (2) on a 5 x 5 matrix; and (3) on a 5 x 7 matrix.

All three problems contained overlapping patterns. The bulbs in each problem fell into three information-yielding categories: (1) "Off" pattern redundant; (2) "on" pattern redundant; and (3) "on" pattern informative.

Only the "on" pattern informative bulbs provided a basis for the choice of the correct model pattern. A one alternative problem required one informative press, a two alternative problem required two informative presses.

Analysis of data

The data were analyzed in terms of achievement in solving the problem, particularly according to age, and the process of problem solving. Three strategies emerged from the analysis of the sequence of bulbs the children pressed in trying to determine to which pattern the bulb board corresponded. The three-year-olds exhibited an enactive approach we have named the Search Strategy. Their performance was characterized by a "quasi-systematic" search of the board for bulbs that would light up. Their searching was quite independent of the model patterns presented. Pressing of edge-bulbs predominated.

Beginning around five years of age a striking and pervasive change was observed, particularly in the children run under the "free" condition. By this age the child's presses became guided or determined by the image of the patterns. The child, however, took each model independently, and successively, mapping it out completely. This testing out was done without apparent concern for the resulting redundancy of the presses. Moreover, "on" pattern bulbs predominated. This strategy, called Successive Pattern Matching, was eventually effective, leading to a solution on even the most difficult problems. It is, however, an inefficient and lengthy strategy.

The third, symbolically oriented strategy was observed around age seven, this time more predominant in the children run under the "constraint" condition. Children who exhibited the Information Selection strategy compared both, or all, models prior to their first press; internally, they selected the bulb(s) that would provide the needed information. Upon questioning, these children could generally verbalize this thinking out of the problem. This strategy, although extremely efficient, is characterized by a heavy cognitive load. This load appears responsible for regressions in some five- and seven-year-olds when they are confronted with overly difficult alternatives. Information selection is quite similar to the focusing strategy as described by Bruner, Goodnow, and Austin (1956).

In sum, then, the earliest strategy is enactively dominated, then an image based strategy replaces it, and finally the child develops a means of dealing with the task informationally rather than ikonically.

Conclusions

In order to solve the problem successfully and to progress from search strategy to pattern matching, a child must achieve certain prerequisites. Foremost is the need for the child to see -- recognize -- correspondence between the bulb board and the model pattern. In addition to achieving recognition, the child must also achieve reproduction. In order to deal with information selection, the child must be able to treat several images simultaneously. This involves mastery of hierarchical organization and feature analysis.

MULTIPLE ORDERING - Jerome S. Bruner and Helen J. Kenney

The means by which the growing child brings order into his world through mastery of the principles of classification and hierarchy is a crucial problem. We have noted previously the sudden appearance of the property of modification in the syntactical structures of the child's language. Inherent in modification is multiple classification.

Inhelder and Piaget (1964) described this development in terms of the formation of logical structures. To continue their investigation we added that logical behavior grows and is sustained by psychological processes. Early in development conflict arises between the sensori-motor or perceptual mode and the symbolic mode (bearing in mind many features simultaneously). In this experiment our objective was to discover the means by which the child develops the capacity to deal with two or more aspects of a situation simultaneously. A procedure involving a matrix arrangement was chosen because it was a logically-complex double classification task, involving the multiplication of classes.

Procedure

The sample consisted of fifty children, ten each of ages 3, 4, 5, 6, and 7. The matrix was a three by three arrangement of nine transparent plastic beakers on a ruled cardboard base. Each beaker varied three degrees, both in height and diameter. The analysis revealed that 3- and 4-year-olds were unable to manage double classification; therefore, a supplementary one-dimensional array of four glasses varying in either height or diameter was added for them.

The task required the child to perform three different operations. The first was replacement, in which first one glass, then two, then three, at a time were removed and the child had to replace them. The child was also asked to describe how the glasses were alike and how different. In the second, reproduction, the position of the glasses was scrambled and the child had to put the glasses back as they were originally. In the third, transposition, the glasses were again scrambled, with, however, the glass originally in the southwest corner now in the southeast (smallest, thinnest one). The child was asked to rebuild the pattern, leaving the smallest glass in its new location.

Analysis of data

The ability to deal with the matrix successfully in the three operations increased with age. As young as five-year-old children were able to replace correctly almost all of the removed glasses in the replacement task. With the younger children, chance for success depended on the number of glasses removed. One-third reversed the glasses when two were removed, and one-half failed to replace the glasses when three had been removed. The ability to

succeed in the reproduction task also increased with age, although performance at all ages was less successful than on the replacement task. Eighty percent of the glasses were correctly reinserted by the five-year-olds. The transposition task was too difficult for all but the oldest children (seven-year-olds), who dealt with it as successfully as with reproduction. Only thirty percent of the glasses in this operation were correctly placed by the five-year-olds.

The nature of the performance at each age level can be described in terms of whether the arrangements made on the reproduction tasks satisfied double classification, single classification, or merely random ordering. The results are clearly shown in Figure 1. Random ordering, quite frequent in the behavior of the younger groups, disappeared between ages six and seven. On the supplementary four glass array the three- and four-year-olds displayed competence in one-dimensional ordering. From five years on multiple dimensional handling in the regular task was evident.

The symbolic structure in the task appeared to affect achievement. In response to the question of how the beakers were alike or different the youngest children displayed an unexpected symbolic difficulty. Differences were easily explained, however, as to similarities, a difference was often given when "how are they alike?" was asked.

Timing the children's behavior yielded little information except for the finding that the better solution required a longer amount of time.

## Conclusions

Observing the children's performance revealed differences in the amount and kind of "perceptual support" that the different situations provided. The youngest children suffered by attending to only one dimension of the glasses, generally that of height. This behavior was responsible for the extremely high proportion of failures in replacing the diagonally located glasses.

When the matrix had been scrambled the younger child was at a loss, although he had reasonable success on an image-bound procedure, whereas the older and consistently successful child appeared to proceed according to a linguistic formula he held in his mind, which described the two dimensional changes. Faced with the transposition task, copying from memory failed the younger child while the older child, working within a rule bound framework achieved success. From the responses to the "alike" and "different" question we conclude, contrary to Inhelder and Piaget's 1958 work, that "relations of similarity are not so easily formed in early life, or if early formed, then surely not easily abstracted from the perceptual whole." Discrimination of similarity and difference may be necessary before linguistic encoding such as "they get fatter in one direction and taller in the other" can be of use.

In addition, from the timing results we conclude that time is a measure of information processing.

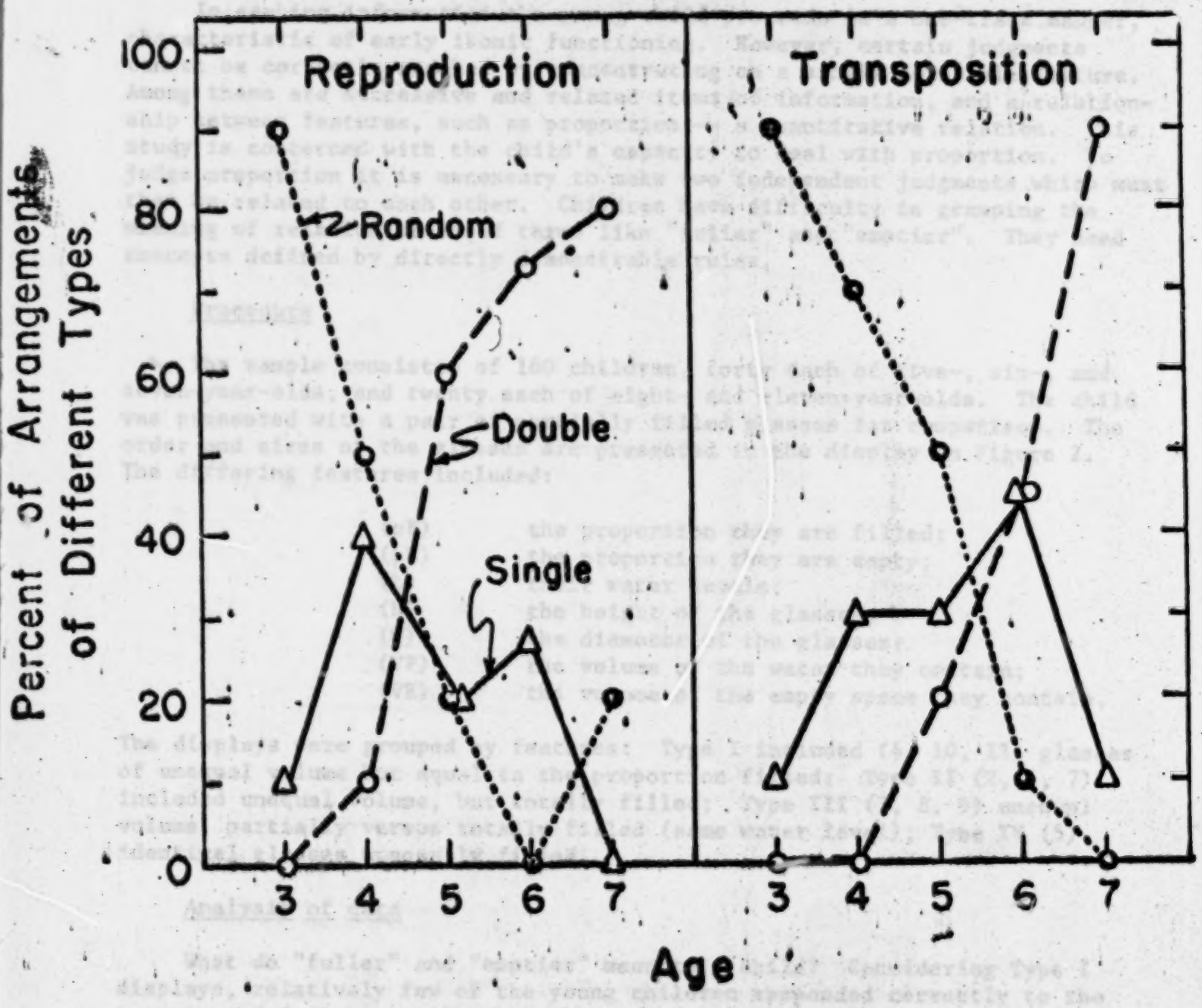


FIGURE 1. Percent of arrangements of different types.

RELATIONAL CONCEPTS - Jerome S. Bruner and Helen Kenney

In seeking information the young child proceeds in a one-track manner, characteristic of early ikonic functioning. However, certain judgments cannot be correctly reached by concentrating on a single pointable feature. Among these are successive and related items of information, and a relationship between features, such as proportion -- a quantitative relation. This study is concerned with the child's capacity to deal with proportion. To judge proportion it is necessary to make two independent judgments which must then be related to each other. Children have difficulty in grasping the meaning of relation-oriented terms like "fuller" and "emptier". They need concepts defined by directly demonstrable rules.

Procedure

The sample consisted of 160 children, forty each of five-, six-, and seven-year-olds, and twenty each of eight- and eleven-year-olds. The child was presented with a pair of partially filled glasses for comparison. The order and sizes of the glasses are presented in the display in Figure 2. The differing features included:

| | |
|---|---|
| (pF) | the proportion they are filled; |
| (pE) | the proportion they are empty; |
| (L) | their water levels; |
| (H) | the height of the glasses; |
| (W) | the diameter of the glasses; |
| (VF) | the volume of the water they contain; |
| (VE) | the volume of the empty space they contain. |

The displays were grouped by features: Type I included (4, 10, 11) glasses of unequal volume but equal in the proportion filled; Type II (2, 6, 7) included unequal volume, but totally filled; Type III (3, 8, 9) unequal volume, partially versus totally filled (same water level); Type IV (5) identical glasses unequally filled.

Analysis of data

What do "fuller" and "emptier" mean to a child? Considering Type I displays, relatively few of the young children responded correctly to the question of fullness. Overwhelmingly the choice of 88% of the five-year-olds to 31% of the eleven-year-olds was that the fuller glass was the taller one with the higher water level. With respect to the emptiness judgment, the response improved slightly; responses in favor of the shorter glass with the lower water level ranged from 66% of the five-year-olds to 81% of the eleven-year-olds. The seven- and nine-year-olds justified their choices by explaining that "fuller" means greater volume of water and "emptier" means greater volume of space. The five- and six-year-olds indicated the height and level of the water. The nine- and eleven-year-olds began to show an understanding of ratio.

## Ratio Procedure

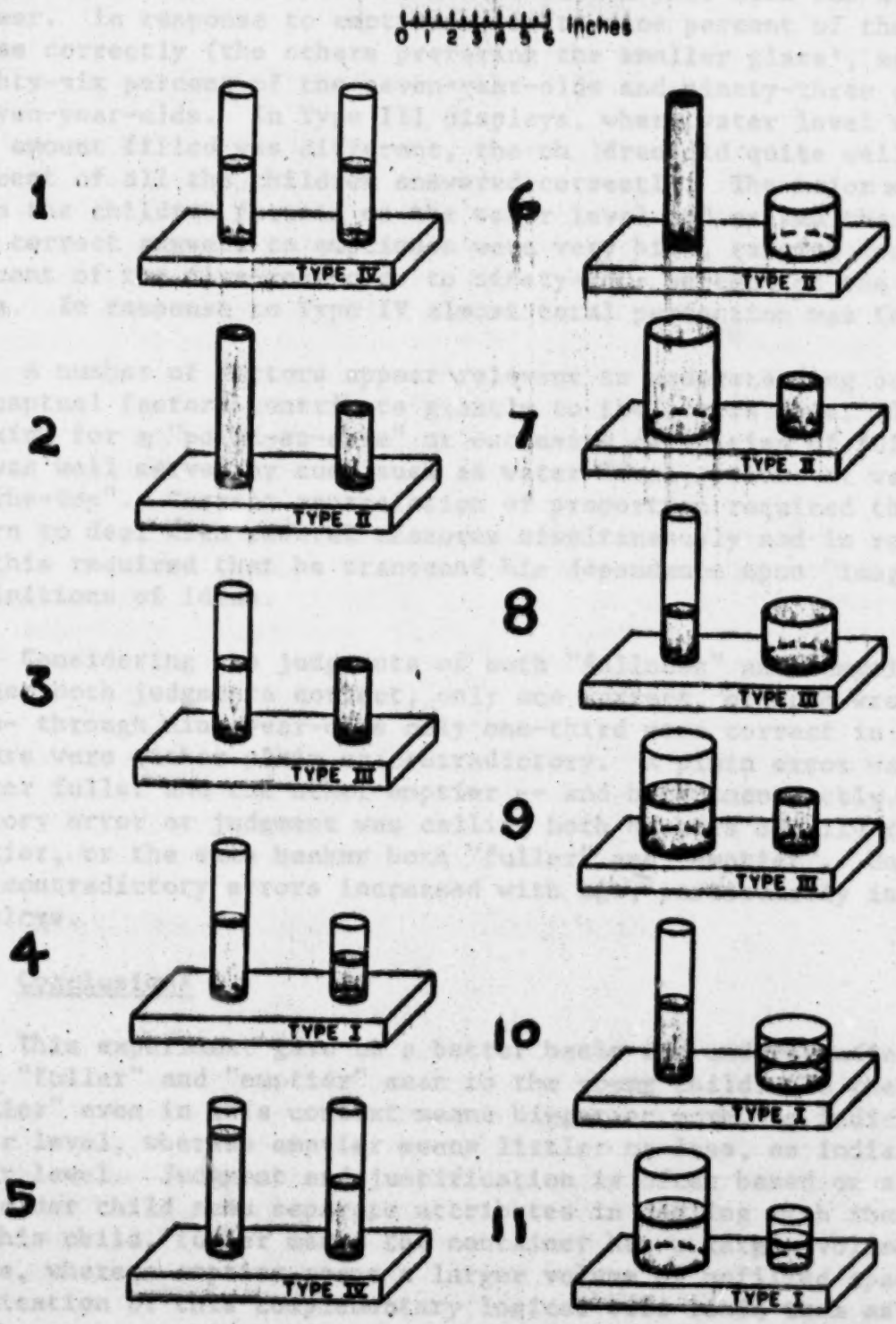


FIGURE 2. Pairs of beakers used in ratio procedure.

The findings for Type II displays, in which both glasses were completely filled, were slightly more encouraging. Forty-five percent of the younger groups and sixty-nine percent of the eleven-year-olds saw equality as the answer. In response to emptiness, fifty-nine percent of the younger children chose correctly (the others prefering the smaller glass), as did more than eighty-six percent of the seven-year-olds and ninety-three percent of the eleven-year-olds. In Type III displays, where water level was the same but amount filled was different, the children did quite well. About fifty percent of all the children answered correctly. The major mistake occurred when the children focused on the water level and called them equally full. The correct answers to emptiness were very high, ranging from seventy-two percent of the five-year-olds to ninety-four percent of the eleven-year-olds. In response to Type IV almost total perfection was found.

A number of factors appear relevant to understanding our findings that perceptual factors contribute greatly to the errors made. The child was looking for a "point-at-able" or ostensive definition of full or empty. He was well served by cues such as water level, volume of water, and "filled-to-the-top". Correct appreciation of proportion required that the child learn to deal with several measures simultaneously and in relation. To do this required that he transcend his dependence upon "image bound" definitions of ideas.

Considering the judgments of both "fullness" and "emptiness" we found either both judgments correct, only one correct, or both wrong. Among the five- through nine-year-olds only one-third were correct in both judgments. Errors were either plain or contradictory. A plain error was judging one beaker fuller and the other emptier -- and both incorrectly. A contradictory error or judgment was calling both beakers equally full but one emptier, or the same beaker both "fuller" and "emptier". Unexpectedly, the contradictory errors increased with age, particularly in Type I and II displays.

## Conclusions

This experiment gave us a better basis for understanding what terms like "fuller" and "emptier" mean to the young child. To the youngest "fuller" even in this context means bigger or more, as indicated by higher water level, whereas emptier means littler or less, as indicated by lower water level. Judgment and justification is often based on a single cue. The older child sees separate attributes in dealing with these opposites. To this child, fuller means the container has a larger volume of filled space, whereas emptier means a larger volume of unfilled space. Consistent application of this complementary logical rule leads them astray, as seen by the number making contradictory errors. Although the older child

now works with two variables., again, the third, the volume of the container is not included. In general, again, it is the critical passage from ikonic to symbolic operations that makes the difference.

THE CONSERVATION OF LIQUIDS - Jerome S. Bruner

The ability to see invariance across transformation in appearance develops relatively late in the child. Piaget (1952) first brought to light through his now classical "conservation experiments" that in Western cultures children do not master the ability to conserve until about seven years of age. In an experiment requiring pouring water between different size beakers, the young child is unable to grasp the idea of the unchanging quantity of water regardless of the container's dimensions. Piaget's explanation of the psychological phenomena depends primarily on the interpretation that the child's newly gained concept of invariance was derived from a "series of quasi-inevitable maturational steps involving the unfolding of logical operations."

The attainment of conservation indicates an important shift in the child's thinking. The child discards his more primitive method of preoperational, overt thinking for the new stage of concrete, internalized and reversible operations. Among the important operations made up of mathematical groups, as described by Piaget, is compensation, the multiplying of relations.

We take issue with Piaget's reliance in explaining conservation on the role first of reversibility and then of compensation. We argue that the basic conceptual aid to conservation is a primitive sense of identity, a notion of sameness regardless of a change in appearance.

Experiment I - Identity and Equivalence

Procedure

This experiment was designed and conducted by Patricia Nair to test the role of identity and equivalence recognition in conservation. The sample consisted of forty-five kindergarten children from a Boston suburb. The children were presented with four plastic boxes described as "lakes". The first two presented were identical, measuring 5" long, 3 1/2" wide, and 2 1/2" deep. The third and fourth boxes were equal in size but different in depth. The third measured 7 1/2" by 5 1/2" by 2 1/2", and the last measured 7 1/2" by 5 1/2" by 4".

The children were pretested on the classical conservation test and designated as either having or not having conservation (see Figure 3). Then the child was presented with two of the boxes, 5" x 3 1/2" x 2 1/2", one pre-filled with water and one which he filled to match the experimenter's. The subject and experimenter then selected a wooden duck for their lakes. The task required the child to move his water and duck to a larger lake (box) and to answer two questions at the time of each move. The question order was alternated: whether there was just as much, more, or not as much water in the new lake (equivalence) and whether the water was the same as the duck had originally (identity). The first move was to an identical box to insure the instructions were understood.

Analysis of the data

In answer to the identity question -- same water? -- almost all of the children with conservation but less than two-thirds lacking in conservation used the term "same water." In answer to the equivalence question -- same amount? -- over one-third of the children with conservation and two-thirds of those lacking in conservation said a change in amount occurred. Children who judged the same amount also saw it as the same water but the reverse was not true. One-third of the children in both groups said it was the same water but a different amount.

Consider next the effect of the order of the questions on the children who said both same amount and same water. For those exhibiting conservation in the pretest, three-quarters of those who received the identity question first in contrast to one-half of those who received the equivalence question first said both "same." This is in comparison with non-conservation children where correct answers were obtained from one-fifth questioned first about identity and three-fifths questioned first about equivalence.

Conclusions

From our findings we can conclude that "a recognition of identity is a necessary if not a sufficient condition for the recognition of quantitative equivalence." The order of asking the questions was also an important variable. In viewing this experiment as a training procedure for helping the child to achieve conservation, asking the identity question first served as a "helpful reminder." For the non-conserver, however, his confusion over the term "same amount" might lead him to consider perceptual differences when this question was asked second. When asked first, however, his reply of "yes" led him to consider "yes" as a satisfactory answer to the question of "same water." Forcing the child to see that the same water must be the same amount irregardless of deceiving perceptual features is the refinement necessary for transforming "primitive sense of identity" into the concept of conservation.

Experiment II - Perceptual Screening

This experiment was designed to aid the child in trying to achieve conservation. Two sources of difficulty, "perceptual seduction" and "insensitivity to contradiction," were designated as the major blocks to

# Conservation Tests

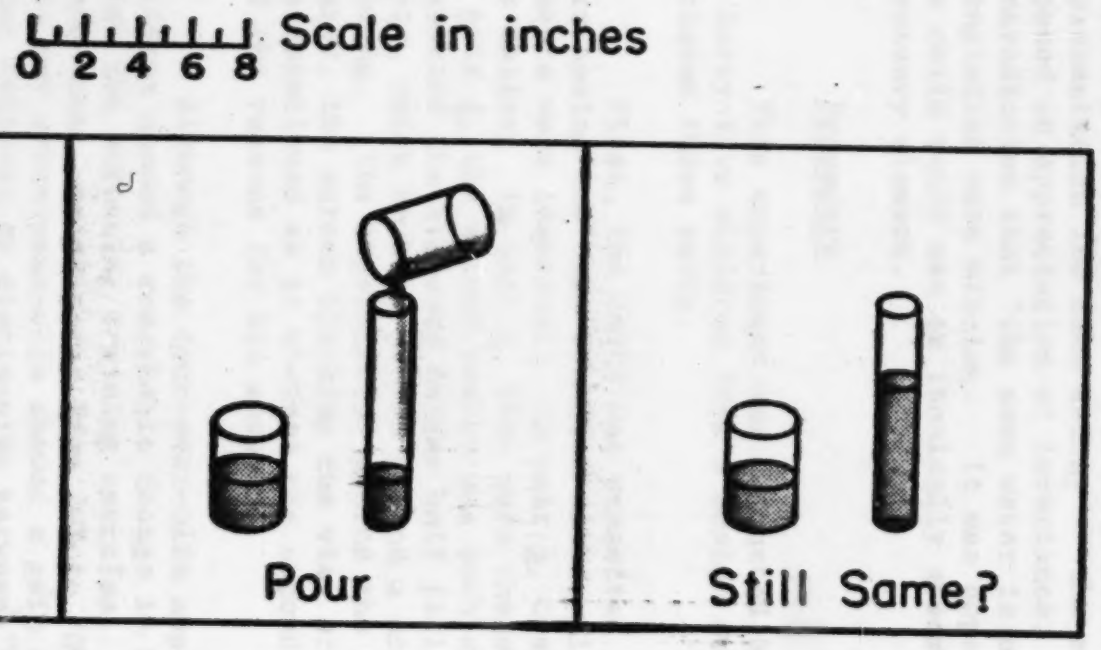


FIGURE 3. The two tests used in classical conservation experiments

achieving conservation. In the "lakes" experiment the misleading ikonic representation led them astray -- the single perceptual feature of water height opposed an appreciation of invariance. The child could not recognize the contradiction that "the same water is not the same amount," as if temporal integration were missing. It was hoped that linguistic representation before the child could see or ikonically assemble the situation might provide the necessary element.

Procedure

This experiment was conducted by Francoise Frank. The sample consisted of forty-five children from a Boston suburb, ages 4, 5, 6 and 7. The experiment included three parts.

First, the child was presented in turn with four pairs of beakers, each pair having the same standard beaker plus a second one. In pair a, both beakers were identical; in pair b, they were the same diameter but the second was taller; in pair c, they were the same height but the second was wider; and in pair d, the second beaker was both wider and taller. The experimenter presented the standard beaker half filled with colored water and the second beaker empty, which he then placed behind a screen leaving only the tops of the beakers showing. The experimenter poured the water from the first into the second beaker, the screen blocking the view of the resulting water level. The child was questioned as to whether the second beaker held the same amount of water, and the reasons for his answer.

Although the four-year-olds appeared too young to benefit, the older children showed a remarkable change in the proportion who achieved conservation after the screening training exercise. The five-year-olds showed the greatest achievement, progressing from 20% to 70% attaining conservation, whereas the six- and seven-year-olds showed a gain of 50% to 90%. The screen forced the older children to distinguish between "how the glasses look" and "how they really are."

Second, the presentation of the beakers was identical to the first part, however, the screen was omitted. The experimenter also requested the child to use his finger to indicate where on the beaker he expected the level of water to come, but no pouring occurred.

With no screen and no pouring, although most of the children showed conservation, correct height predictions varied by age. Whereas only 10% of the four-year-olds showed an understanding that the water level will drop, 70% to 90% of the older children predicted the correct level.

Third, the beakers were presented in the same order with the screen in place. The child drew a line on the screen corresponding to the water level in the standard beaker. Then the experimenter poured the water as in the first part. The child was questioned as to "same amount" and also was asked to draw a second line on the screen to indicate the water level in the second beaker.

In contrast to the first and second parts, the screen was then removed. The child after seeing the water level was questioned as to "same amount" and his reasons.

When in the last part the screen was removed, the four-year-olds who previously achieved conservation regressed to non-conservation; but the older children whose answers indicated a confusion between changing water level and knowledge of identity, were able to maintain conservation. Pair b involved two beakers, 6" and 8" with the same diameter; although all ages were equally successful in predicting there would be the same amount in the taller beaker, the younger children were far more successful in predicting the correct water level. The two errors which "trapped" the older children were (1) misuse of the principle of compensation, (2) misuse of the idea of a ratio. Nine in ten of the pretest conservation children committed one of these errors. This was but another of the many examples of "growth errors" which appeared in our experiments.

The reasons given (in reference to pairs c and d of different diameter) fell into one of three categories, and reflected age differences. For those giving conservation responses perceptual reasons were rarely given. The answers were divided between identity or conflict, accounting for why it is the same although it looks less. For the younger non-conservation children the opposite distribution occurred; perceptual and identity reasons ranked high. For the six-and seven-year-olds lacking conservation, perceptual reasons decreased to about 16%, identity reasons were given in 57% of the cases, and conflict reasons in 27%.

## Conclusions

The data indicate that, in contrast to those lacking in conservation, children who have achieved conservation use fewer immediate perceptual cues in making judgments about "amount to drink." The screening procedure aids the children, particularly the older ones in basing a decision on less direct perceptual cues and in sensitizing the child to the conflict between appearance and reality. Evidence also exists to prove that since reversibility and compensation are active in situations where the child lacks conservation, they themselves are not the producing or responsible factors. Learning to predict correct water level is far more frequent (4 times greater) than recognizing equality of amount.

## Experiment III - Compensation and Reversibility

This experiment was devised to discover how children who had not achieved conservation would respond in a less verbal situation.

## Procedure

The experiment was designed by Susan Carey. The sample consisted of nineteen four- and five-year-olds who were given five "tests." In front of the child were a partially filled standard beaker and an empty, identical one designated as "his glass." The child was presented with five displays of two partially filled beakers shown in the display (see Figure 4) and was instructed to choose the one which contained just the amount of water which would make "his glass" the same as the other glass. The child was queried as to the reason for his choice and then allowed to check by pouring.

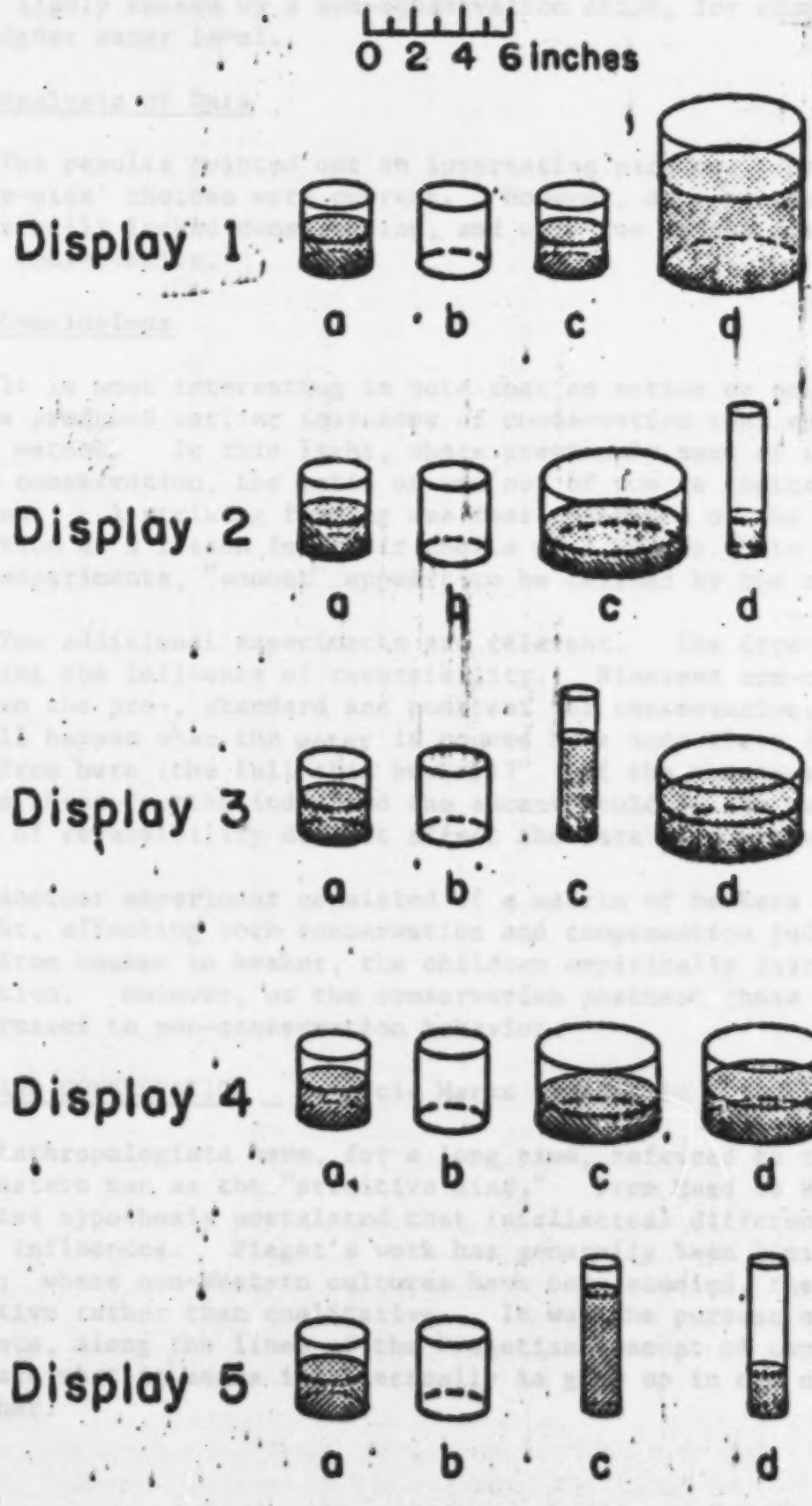


FIGURE 4. Displays for compensation in action.

The correct choice of the two beakers was particularly devised to be the one most likely chosen by a non-conservation child, for example, a narrower one with a higher water level.

Analysis of Data

The results pointed out an interesting paradox. Half of the four- and five-year-olds' choices were correct. However, on a posttest, all the four-year-olds still lacked conservation, and only two of the five-year-olds had achieved conservation.

Conclusions

It is most interesting to note that an action or enactive oriented procedure produced earlier instances of conservation than obtained in testing by Piaget's method. In this light, where previously none of these children achieved conservation, the ratio of one out of two is logically and statistically significant. A striking finding was that one-third of the children gave compensation as a reason for their choice of a beaker. In these and other similar experiments, "amount" appears to be defined by the child as "water level."

Two additional experiments are relevant. The first was to aid in determining the influence of reversibility. Nineteen non-conservation children were given the pre-, standard and posttest for conservation. They were asked "What will happen when the water is poured back into there (the empty standard beaker) from here (the full thin beaker)?" Of the thirty-eight answers given more than three-fourths indicated the amount would be the same. Therefore, the presence of reversibility did not affect the lack of conservation.

Another experiment consisted of a matrix of beakers varying in diameter and height, affecting both conservation and compensation judgments. Through pouring from beaker to beaker, the children empirically learned the rules of compensation. However, on the conservation posttest these four- and five-year-olds regressed to non-conservation behavior.

CULTURE AND CONSERVATION _ Patricia Marks Greenfield

Anthropologists have, for a long time, referred to the cognitive powers of non-Western man as the "primitive mind." From Mead to Whorf, the relatively unsupported hypothesis postulated that intellectual differences are due to cultural influences. Piaget's work has generally been limited to Western cultures; where non-Western cultures have been studied, the emphasis has been quantitative rather than qualitative. It was the purpose of this set of experiments, along the lines of the Piagetian concept of conservation, to investigate what it means intellectually to grow up in one cultural milieu and not another.

Procedure

This experiment was conducted with the Wolofs in Senegal, West Africa. The sample consisted of three basic groups subdivided by ages. The first were rural unschooled children and adults who had neither school nor urban influence. They were in the village of Taibe N'Diaye. Four age groups were differentiated, although age data are only approximate. There were seventeen six- and seven-year-olds, twenty eight- and nine-year-olds, twelve eleven- and thirteen-year-olds, and adults.

The second group consisted of Bush school children, receiving a French style education, from the same or neighboring villages. The school grades selected were chosen to correspond with the above age groups: twenty-three first graders, twenty third graders, and twenty-four sixth graders. The third group consisted of city school children from Dakar, Senegal's cosmopolitan capital. Again grades one, three, and six were included. All children were interrogated in Wolof, except for special language conditions to be described, although French was the language of school instruction.

In the basic conservation task, a child faced with two partially filled identical beakers, would equalize the water levels. The experimenter subsequently transferred the water in one to a second, taller, thinner beaker. The child was then asked in Wolof, "Does this glass of yours or this glass of mine have more water; or does this glass of yours have more water?" (This form was chosen to overcome some ambiguity in Wolof for "equal.") The children were also asked, "Why does this glass have more (or equal) water?" In the second part of the experiment six shorter, thinner beakers replaced the long one, and the procedure was repeated. (See Figure 3).

Two instructional techniques were used, similar to those previously described in studies carried out near Boston.

Analysis of data

Our findings show that the development of conservation among the unschooled Senegalese is not identical to that found in our studies of American children. One of the most striking findings was that among the unschooled, by eight or nine years of age conservation ceases to be related to age. The school children, from both bush and village exhibited similar developmental trends as their Western counterparts. By eleven or twelve years of age (sixth grade) virtually all school children have achieved conservation in contrast to only one-half of those not in school. The Dakar school children exhibited relatively poor conservation achievement performance until the sixth grade when their performance equaled that of the Bush children. From then on, however, the school children's behavior was far superior.

More interesting is an analysis of the children's reasoning. Their justification for saying equal or unequal is based on one of three things: perceptual reasons, direct-action reasons, referring to pouring of water, or indirect action or transformatinnal reasons (operational, internalized action). The Wolofs, like American school children, show early reliance on perceptual reasons, and a later decline in such reasoning. In contrast, the unschooled

Bush children show gradual increase in perceptual reasons during the same age span. In looking at the children who achieve conservation, transformational reasons are a necessary, if not sufficient, basis for achievement.

Of 181 reasons, in support of conservation:
40 percent of the reasons are based on perceptual features,
16 percent are based on direct action,
44 percent are transformational
and in support of nonconservation, they were:
78 percent are based on perceptual features,
20 percent are based on direct action,
2 percent are transformational.

The growth of a sense of identity, the concept of continuity of an initial state, emerges from the results as central to the attainment of conservation. Most of the transformation reasons, as well as many of the direct action reasons, justifying conservation are based on the principle of "identity." Reversibility appears secondary to identity as a necessary condition for conservation.

The unschooled children's behavior reflects "seduction by the experimenter's action" or "action-magic" as the major reason for their inequality judgments. Schooling, however, abolishes such incorrect justification.

As for any influence of the urban environment, Dakar children do not as one might expect, pay more attention to diverse perceptual cues; rather, they are restricted to a single impression.

The "screen" technique was introduced in this study in order to better investigate the interaction of broad cultural influences and specific training procedures. It was hoped that this procedure would protect the child from the domineering effect of perceptual inequality. In the American study the screen was a success. It was of some question if this procedure would prove equally successful "among children whose language indicates little concern with noting and reconciling self-consciously the differences between appearance and reality." Pouring operations were first carried out behind a screen leaving only the tops of the beakers visible. The child was questioned with the screen in place, and a second time, after the screen was removed. Screening was not comparably successful in aiding the 81 Wolof children to attain conservation. In contrast to successful achievement of conservation in 61% of the posttest non-conservating children, only 30% of the Wolof children showed a change in performance. Upon closer inspection most of the "successful" children proved to have exhibited fluctuation and possibility of conservation in the pretest.

One of the major blocks to achievement of conservation particularly prevalent in the rural group of unschooled Senegalese children appeared to be the "magical powers" the child assigned to the experimenter when justifying an incorrect judgment. To combat such an effect the testing procedure was altered slightly so the child did all the pouring himself. Data was analyzed for the child's judgment of equality in this situation and transferred to two successive posttests where the experimenter poured.

A startling favorable difference in behavior in the younger and the older children was observed in both the self-pouring procedure and the two post-tests. In the standard testing situation one-quarter of the younger children and less than one-half of the older ones achieved conservation. In the self-pouring situation two-thirds of the younger children and four-fifth of the older ones achieved conservation. Data on these children confirmed a strong transfer of conservation in the subsequent posttests.

Conclusions

Several points were made salient from this investigation.

School, not rural versus urban environment, appears to be the highly influential variable. Without schooling, we may conclude, general intellectual development is arrested by eleven years.

It appears that school attendence first increases the youngest children's attention to perceptual features; this in turn is followed by a systematic reduction of the importance of these features. This trend is opposite to that found among the unschooled.

In contrast to results with American children the "screen" procedure was pedagogically ineffective in helping the Senegalese children to attain conservation. An unusual reasoning among the unschooled children was the "action-magic" variable. This was effectively blocked by having the child do the pouring himself. "Action is crucial to their representation of the world."

Unlike the American child, the Senegalese cannot deal simultaneously in the present with "appearance" and "reality."

However, the Senegalese experiments provided further support for the hypothesis that identity is logically and psychologically sufficient for a conservation judgment.

The Greenfield studies taken in conjunction with Biesheuvel, Price-Williams, Gay and Cole, and Schmidt leave very little question about the profound effect on intellectual development of the first few years of school between ages six and twelve. Whether one is examining perception, problem solving or memory origination, the effect of schooling is enormous and makes the school child in Senegal much more akin in mental characteristics to the suburban child of Boston than he is to the unschooled child in his own culture. This extreme statement holds, of course, only for the strategies with which the child approaches tasks of problem solving and information processing.

## STUDIES OF SELECTIVE VISUAL ATTENTION

The central theme of these contributions is a matter which many regard as one of the most important of all in psychology. Every time an individual uses his eyes to perceive, he is making a choice. All visual attention is, therefore, a selective action. No one can possibly attend to all the stimuli with which he is surrounded; some of the signals will be blocked. We have, therefore, been interested in how adults and children turn their attention to some features in the environment at the expense of others. One of the most frequent and effective ways of directing the attention is obviously to turn the eyes towards the center of interest. It is, therefore, fortunate that some completely new procedures have become available to record the position of the line of sight. One of these methods is embodied in a device called the Stand Eye Camera, which was developed by Dr. Norman H. Mackworth.

### SELECTING VISUAL INFORMATION DURING RECOGNITION BY ADULTS AND CHILDREN

-- Norman H. Mackworth and Jerome S. Bruner

This experiment was designed to determine how children and adult eye fixations are affected by (1) the sharpness of focus of a picture and (2) knowing beforehand what an out-of-focus picture represents.

#### Procedure

The sample consisted of fifty subjects, thirty adults and twenty children. Ten adults and ten children inspected a colored photograph of a fire hydrant, seeing first a blurred, then an intermediately clear, and finally a focussed picture. Another group studied the same stimulus picture going from sharpened to blurred. The third group of ten adults studied pictures of an ashtray progressing from blurred to focussed. The pictures were each presented twice, for 10 seconds at a time.

The Stand Eye Camera recorded the positions and sequence of the eye fixations directly on to a Polaroid photograph of the original display. (Figure 5).

#### Analysis

Sixteen different ways were devised to measure the changes in the position of the line of sight made while the subject attempted to understand the picture. The effective search score was found to be unusually sensitive because it measured some of the effects of comprehension. The measure included the extent to which the eyetrack covers the picture as whole, and the extent to which the gaze rests on particularly important areas in the picture. This measure has shown that six-year-old children are less capable than adults in meeting either of these two requirements for effective processing of visual material in pictures. The same index of measurement has detected a falling off in performance when the subjects have to comprehend pictures rather than simply to inspect them.

A SIX-YEAR-OLD DOING A VISUAL SEARCH TEST IN THE STAND EYE CAMERA Figure 5

In addition to the effective search score, measurements included fixation durations, fixation density, the rated search score, total length of eye-track, repeat index of consistency, length of separate eye-movements, and the direction of eye-movements. The variables -- degree of blurring, sequence of presentation, age of subject, and first or second presentation -- significantly affected some of these scores. Blurring affected every analysis.

Cognitive effects were also evident in that fixation times increased considerably when ambiguous scenes had to be comprehended rather than merely casually explored. Furthermore, the identification of these blurred images greatly altered the direction of the longer leaping movement of the images across the display. The eye-camera procedure can, therefore, indicate the elements of a scene that the subject is trying to relate while he is solving some recognition problem.

OUTSTANDING VISUAL STIMULI DOMINATE LOOKING AND SCALING CHOICES: VISUAL AND VERBAL RESPONSES TO PICTORIAL DETAILS -- Norman H. Mackworth and Anthony J. Morandi

Using three groups of 20 subjects each, this study attempted to determine the relationship among subjective ratings of informativeness of 64 squares comprising a picture, time required to locate individual squares, and the number and position of eye fixations that could be identified when subjects viewed the entire scene. In Part I, 20 observers were asked to rate in order of amount of informativeness squares approximately 1 x 1 inch in size. All the squares, two groups of 32 squares, comprising each picture were presented to each observer and they rated them on a scale between 0 and 9. Subjects were consistent in giving higher ratings to the same squares and lower ratings to others. Part II involved a second group of 20 subjects, who were presented one-half of each picture, i.e. 32 alternative squares were missing. Each observer was given five pictures and two sessions were provided. In the second session, the second alternate 32 pieces of the picture were presented. Subjects were given each square in proper orientation, individually, and timed in seconds from presentation until its right location was found. Maximum time for each square was arbitrarily set at 120 seconds and five readings were obtained for each square. No subject was given the same square more than once. Those squares which were previously rated high in informativeness were most quickly located; those least in informativeness, in most cases, took approximately 5 times longer to find. Part III involved the presentation of the entire scene to 20 other observers. Eye fixations were recorded with the Mackworth Stand Eye Camera.

Analysis

Analysis of eye fixations when viewing each scene for 10 seconds indicated that subjects tend to be consistent in concentrating on those areas which are rated high on informativeness. A few outstanding areas usually dominated the display each time. The other result was that redundancy in patterns can be detected by high rated values of informativeness plus low fixation densities.

FREQUENCY OF VISUAL FIXATIONS IN INFORMATIVE AREAS IN PICTURES --
Dale R. Schissler and Norman H. Mackworth

Three methods are reported for obtaining subjective ratings of informativeness for small areas of a picture. It is shown that the ratings are highly reliable. As a check for whether the ratings of the areas are meaningfully related to the whole picture, the ratings are correlated to records of eye fixations for the same picture. A significant positive correlation is shown. Estimates of peripheral informativeness of areas are derived and show a high positive correlation with fixations. It is argued that this supports the idea that peripheral vision (greater than $2^{o}$ by $2^{o}$ of visual angle) is important in the distribution of fixations.

Conclusions for these studies on selective visual attention

When people are selecting certain parts of a picture, they are in fact concentrating their gaze on a relatively small portion of the total area, usually no more than about 10-15 percent of the entire display. The group fixation patterns cluster around key regions which contain the main information-bearing areas of the picture. These studies describe how the eyes seek out these special areas in the displays. Our findings also clearly demonstrate that fixations and informativeness go together when informativeness is regarded simply as the estimated ease of recognizability. In fact, people will usually seek out the informative areas. However, there is one important proviso: the picture must not overload the subject with information, for then the fixation pattern becomes more evenly distributed.

Although adults were more effective than children at finding these important areas, there was only slight difference between the speeds with which their eyes were looking at the picture in terms of the average fixation time representing the average length of pause. The data suggests quite strongly that adults are unable to process visual information in the form of pictures as readily as words. The reasons for this are believed to be important since they center on the fact that it is difficult even for adults to group isolated stimuli into composite visual segments. Ways are now being sought to define such grouped stimuli because these are the visual inputs that allow people to comprehend pictures. Adults, for example, may well be able to perceive a whole mass of information from a small fragment of the whole. Clearly, however, the recognition and processing of pictorial information is much more than the external stimuli. Of fundamental importance to educational psychology is the way in which people manage to combine these external signals with the internal impressions they have already formed from previous experience. People group things together into classes of objects so as to understand the intangible internal hypotheses that have been built up by long-term and recent experience. Eye camera studies may help to distinguish between the two ways in which people seem most often to classify a new item. There are those who go by a list of general rules and those who use specific little pictorial quirks or oddities in the patterns.

## STUDIES OF THE USEFUL FIELD OF VIEW

Our work on the selection of visual information also brought to light another difference between child and adult perception. The children's records showed rather more very small eye-movements between visual fixations. This was not simply a matter of the eyesight of the children. At times the same children could also achieve some very large eye movements between their fixations. We believe the main explanation for the small distances between fixations may be found in the assumption that the children experienced greater difficulty with this display. This is known to be true in reading, where children quite normally have small visual steps owing to the same difficulty of comprehending the material.

The theory is that when children discover that they have too much visual information, then an automatic reaction occurs which limits the area around the fixation point from which information is being extracted and used. Therefore, the useful field contracts with too much information just as the pupil constricts with too much light. This is protective in the sense that it reduces confusion by removing the overload so likely in the one-track mind of a six-year-old.

The useful field of view, then, is the area around the fixation point from which information is being processed in the sense of being stored or acted upon during a given visual task. It follows that the size of the useful field is likely to be a valuable measure of the extent to which the immediate visual surroundings are overloading attention. Two different kinds of investigation have been undertaken on this interesting phenomenon of contraction of the visual field upon overloading.

### MEASURING THE USEFUL FIELD OF VIEW DURING VISUAL SEARCH --
Norman H. Mackworth and Joyce M. Hiebert

This study was designed to demonstrate that the visual field does contract during visual search.

#### Procedure

This was a strip scanning experiment requiring inspection of dense and, on some occasions, sparse displays. The sample consisted of twenty subjects. The stimuli presented were display strips varying in width from $1^{\circ}$ or one-half inch to $6^{\circ}$ or three inches. The display contained small black squares. Some displays lacked any squares. The subjects were required to scan these displays closely to detect the presence of the squares. The useful field of view was measured by certain characteristics of the eye tracks recorded during this visual scanning.

#### Analysis

When the useful field was quite adequate to extend right across the width of the narrow display strip the eye tracks made were almost straight. As soon as the display strip was widened beyond the visual width being used, the eye tracks started to turn much more frequently away from the long axis

of the narrow display strip. Not only did the eyes travel along the strip but they moved sideways as well in an attempt to compensate for this field inadequacy by scanning movements. The number of these turns in the eye track away from the long axis of the best strip was found to be a most satisfactory measure of the size of the useful field of view employed during visual tracking. Furthermore, longer fixation time was observed and there was a greater tendency to mass the target signals. These changes occur because the subjects attempt more stimuli per fixation when the strip is widened.

VISUAL NOISE CAUSES TUNNEL VISION -- Norman H. Mackworth

This experiment, using different displays, was designed to demonstrate that visual noise causes tunnel vision -- that unwanted stimuli narrow the field of view.

Procedure

A flash tachistoscope was used. Letters were spread the width of the display, ranging upwards from three letters. The task required the subjects to recognize what was being flashed.

Analysis

The results were basically the same as found during visual search. When target letters alone were presented, the subject could recognize the flash exposure much more easily than when unnecessary letters were added.

Conclusions on the useful field of view

The findings to date with these methods indicate the size of the useful field of view is much smaller than one might expect from predictions based on visual acuity calculations alone. Secondly, the size of the useful field of view becomes even smaller than normal when the presentation display is crowded with unwanted signals which have to be discarded during the search for the important details. These effects are much less marked for sparse displays.

## CONCLUSION

In conclusion, our views concerning intellectual growth and the nature of knowing as manifest in the preceding pages can best be summarized by the term instrumental conceptualism. This view rests on two fundamental principles. First, what we consider as knowledge is, in effect, a constructed model of reality, a model which is, however, removed from the possibility of direct or complete testing. To the extent to which testing is limited, we must say that our cognitive models, as of ideas of the continuity of time and space, and ideas of cause and effect, have an axiomatic base. These "givens" in our experience force us to construct our models of reality in a particular way. So it seems not unlikely that some of this axiomatic structure is clearly innate in the nature of our techniques for the representation of reality: action, imagery and symbolism.

The second tenet considers that models develop in a dual role as a function of the uses imposed by both the culture and by the individual. Therein lies the difficulty in differentiating between cultural versus individual instrumentalism. The values dominant in a culture have evolved from the way the culture has dealt with circumstances; and the "values-in-use" reflect an individual's particular mode of coping within the culturally allowed limits.

Intellectual growth in man results from internalization of ways of behaving, as does subsequently, the development of man's powers. This development rests on three imbedded predicaments: the amplifiers existent within the culture, the demands placed on the individual according to his mode of living, and the extent to which the culture or specific institutions therein demand confirmation between the three modes of representation. When learning occurs outside the immediate perceptual field, correspondence between doing, seeing, and saying is necessary. Technical societies also encourage increased translatability between the systems, with a tendency to reflect acts or imagery not relatable in other forms.

Growth errors, as seen among older children working on the ratio problem, are an outcome or manifestation of discordance between the systems of representation. During the growth years a child often becomes more mistaken about representation before a final understanding is achieved.

With respect to information seeking, the method of search changes in a regular way with growth. The progression begins with the child paying attention to single perceptual features of the environment, then proceeds to image-matching. Subsequently the child's behavior is characterized by attending to several features simultaneously which he can arrange in a hierarchical structure. Thus develops information analysis.

It is our belief that this progression of perceptual analysis holds universally, across cultures. The differences, we propose, occur as a result of the greater push toward hierarchical connections in technical societies. Perception remains more <u>ad hoc</u> in the less technical societies. In the more primitive cultures it is unlikely that events will need to be related to occurrences outside their immediate contextual setting.

Our work on invariance or conservation of form across transformation in appearance also pointed up a developmental sequence. The young child, who appears to lack conservation when tested in the classical manner, is capable of conservation-based actions as seen in the self-pouring technique. The stumbling block appears to be the difficulty the child has in ikonically representing the primitive identity concept. Children in less technical societies such as Senegal never achieve "verbal" conservation. In the end, we are increasingly struck with what occurs in a highly evolved technical society. It is not that one sees "better" or represents what one has learned in habit patterns "better," or even talks or thinks in language "better." Rather, what seems to be the case is that there is an insistence on mapping each of these systems into another, with a resulting increase of the translatability between each of them. We tend to reject those acts that do not lend themselves to a linguistic rendering or accountability, and perhaps to rule out of imagery those features of experience that have no enactive counterpart or no words or sentences that render them communicable.

Robert Leeper (1965) has written a brilliant and timely piece on the perceptual representation of emotions and motives. He conceives motives and emotions as making themselves felt through their participation in cognitive organization. We believe that, where the emphasis of a technical society is on objects and acts in their abstract and linguistic connection, we may be missing the conditions for satisfying those human needs that are not related to objects, to instrumental acts, or to abstract hierarchies. We have remarked on the increasing instrumental power that comes from "forcing" a confrontation between the three systems of representing reality. It is a proper precaution to comment on the potential dangers of insisting that our acts and images should conform to the austere hierarchies of lexicon and grammar. The functional adequacy of the hunter-gatherer, or the organic quality of design in folk societies, may require that there be not only some means by which we may achieve a unity of representation, but also one that leaves room for mute emotions and inexplicable motives.

But lest we seem either to celebrate the noble savage or to look darkly at the intellectual future of man, we should state one final conclusion that is crucial. In so far as man's powers are expressed and amplified through the instruments of culture, the limits to which he can attain excellence of intellect must surely be as wide as are the culture's combined capabilities. We do not know in any deep sense as yet how we shall, in the future, empower men better. In so far as the sciences of knowing can throw light on the growth of mind, the efficacy of the culture in fulfilling its responsibility to the individual can likely be increased to levels higher than ever before imagined.

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